The Motion of Σ 1819. By S. W. Burnham, M.A.

Since the first measures of this pair by Struve, in 1828, the companion has passed through an arc of nearly 90°. During this interval it has been frequently measured by most of the double star observers. It is always an easy pair, as the distance is never less than 1″, and the components are sensibly equal in magnitude. The only orbit of this pair was computed by Casey in 1882, using measures from 1828 to 1877 (*A. N.* 2421). Some of the measures made during this interval were omitted, but this could not materially affect the conclusion. He found a period of 340·1 years. Subsequently, Berberich challenged the correctness of this result (*A. N.* 2518), and showed that the measures could be well represented by rectilinear motion, and that therefore the relative change was probably due to proper motion. So far as one could judge alone by the residuals resulting from his comparison of the measures as a whole with a right line, a good *primâ facie* case was made; and if the claim had been simply that at this time, in consequence of the shortness of the arc and the errors of the observations, no ellipse could be drawn to represent these discordant measures, which would be more likely to be the correct orbit than any one of many others which could be substituted, there would be nothing further to be added until the observations cover a much longer time.

But when we consider all the circumstances, the proper motion of the system as a whole, the relative magnitudes, and particularly the distance between the components, and the measures, such as they are, there seems to be no reasonable doubt that these stars form a binary system. We may further consider that although the measures can be apparently well represented by rectilinear motion, still when the character as to accuracy of all such observations is taken into account, such argument has very little bearing upon the question. That these measures are many of them bad—inexcusably so—is obvious enough from a casual inspection; but they are no worse than the measures of all pairs of this class which cover a period of sixty years. If the measures which have been used in computing the orbits of any of the long-period binaries, where no question has been raised as to the character of the relative motion, were submitted to this test, it would be found in every instance that the motion could be substantially as well represented by a straight line. This will explain the enormous discrepancies in the periods of the same pair by different computers where the angular change is small. We have periods of *Castor* ranging from 250 to 1,000 years, of σ *Coronæ* from 195 to 845 years, and λ *Ophiuchi* from 89 to 370 years. Many other similar instances might be cited, but it is sufficiently evident that if two independent investigators should reach the

same result, it would be due to the accident of their treating discordant observations in the same manner. Anything from a circle to a straight line will represent the measures in nearly all of these small arcs, and the most laborious and thorough analytical investigation is not likely to give any better result than would be obtained in a moment's time by simply taking the angular motion as uniform throughout the apparent orbit. In this connection an examination of the widely differing results obtained of stars of the class under consideration, given in Gore's *Catalogue of Binary Stars*, will be instructive. There is no doubt whatever, in most instances at least, of the physical connection of these stars, but the data are wholly insufficient for the determination of the periods and other elements of the orbits. It is very questionable if it is worth while spending any time in the investigation of the orbit of any binary where the arc representing the angular motion is not at least 180°. Certainly in the majority of instances not even an approximate result can be obtained. If the measures were free from errors, then, of course, one ellipse, and only one, would represent them; but with the material we have, and particularly where it runs back nearly to the beginning of micrometrical work, a great variety of curves will satisfy the observed positions equally well, even when one-half of the orbit has been passed over. The fact is that the best-known orbits are those of double stars discovered in the last fifteen or twenty years.

In looking up the question of the motion of Σ 1819 it was necessary in the first instance to collect all the measures down to date. As these will be wanted in some future investigation, I give them here:—

Measures of Σ 1819.

Date.	P.	D.	*n*	
	°	″		
1828·35	88·0	0·86	2	Struve
1832·42	84·9	1·10	2	Struve
1836·43	76·1	1·13	4	Struve
1841·35	65·2	0·95	1	Mädler
·93	66·4	1·07	2	O. Struve
1842·40	63·2	0·87	3	Mädler
·81	60·5	1·08	3	Dawes
1843·24	62·8	...	7	Kaiser
·34	61·9	1·02	1	Dawes
·34	61·2	0·94	1	Mädler
1844·35	62·0	0·83	1	Mädler
1845·38	57·1	1·04	1	Mädler
1847·41	54·1	1·16	5	Mädler
1849·36	52·9	1·19	2	O. Struve
1851·29	49·6	1·27	5	Mädler
1852·39	46·1	1·02	1	Mädler

Date.	P.	D.	*n*	
	°	″		
1853·42	45·3	1·09	2	Mädler
1854·39	44·4	1·14	4	Mädler
1856·39	43·7	0·93	2	Secchi
·41	47·4	1·19	1	Mädler
1857·42	42·7	1·05	1	Mädler
·82	41·6	1·1	10	Dembowski
1858·38	38·2	1·0	1	Mädler
1859·45	39·4	1·00	1	Secchi
1863·01	32·3	1·29	11	Dembowski
1864·41	34·5	1·17	2	Secchi
1866·42	36·5	1·43	1	O. Struve
·49	30·5	1·21	8	Dembowski
1867·28	31·9	1·94	...	Talmage
·31	33·5	1·03	2	Searle
1868·18	34·1	0·88	1	Searle
1870·36	26·2	1·23	3	Gledhill
1871·31	26·1	1·35	3	Gledhill
·69	24·2	1·31	9	Dembowski
1872·38	24·8	1·19	2	Wilson & Seabroke
1873·32	25·3	1·28	2	Wilson & Seabroke
1874·41	23·2	1·33	1	Wilson & Seabroke
1875·36	21·6	1·47	4	Schiaparelli
·38	24·1	1·40	1	Wilson & Seabroke
1876·41	23·2	1·37	1	Wilson & Seabroke
·41	20·1	1·26	3	Hall
·59	19·9	1·18	5	Dembowski
1877·33	17·2	...	2	Doberck
·37	19·0	1·23	1	Plummer
1878·40	17·8	1·22	2	Doberck
·42	20·4	1·38	2	Wilson & Seabroke
1879·40	18 6	1·49	4	Schiaparelli
·49	19·2	1·20	2	Wilson & Seabroke
1880·37	14·3	1·34	4	Hall
1881·39	15·7	1·26	4	Hall
·45	15·9	1·56	3	Schiaparelli
·46	15·1	1·45	1	Hough
1882·30	16·2	1·27	2	Doberck
·41	14·9	1·32	3	Hall
·45	17·2	1·60	4	Schiaparelli
1883·42	13·8	1·35	2	Hall

Date.	P.	D.	*n*	
1883·46	14°·6	1″·53	5	Schiaparelli
·46	14·6	1·25	1	Seabroke
·85	17·0	1·52	7	Engelmann
1884·42	13·7	1·33	3	Hall
·45	14·7	1·49	5	Schiaparelli
1885·37	11·8	1·32	3	Hall
·41	11·4	1·39	2	Perrotin
·45	12·1	1·50	5	Schiaparelli
·52	12·0	...	2	Smith
1886·43	12·1	1·39	3	Hall
·47	12·2	1·54	2	Smith
1887·35	14·9	1·28	3	Tarrant
·38	11·1	1·28	4	Hall
·43	10·0	1·33	5	Schiaparelli
1888·39	8·0	...	1	Smith
1889·32	1·4	1·05	2	Highton
1890·45	9·1	1·53	2	Glasenapp
1891·46	5·7	1·62	2	Collins
·49	9·5	1·42	3	Maw

The discordances are large, and it is clear that we must in some way get a mean line which will represent as fairly as possible the path of the star as derived from all the measures. I know of no better way in this particular instance than that followed in the diagrams illustrating my paper on "Invisible Double Stars" (*Monthly Notices*, 1891 April), and I have accordingly laid down each one of these measures, when both angle and distance are given, on the diagram, plate 9, fig. 1, the angles being shown on the horizontal scales and the distances on the vertical scale. The consecutive measures are connected by lines, so that any one can be readily identified. The long curved line was then carefully drawn through these observed positions, so as to represent them as a whole as accurately as possible. The distances of points on this line at intervals of 5° were then taken from the diagram for the 85° represented by the observations, and laid down on the diagram, fig. 2, in the usual way from the central star. These seventeen positions are shown by the white circles. Then an ellipse was drawn which should pass through these several points as nearly as possible.

As a further check, and illustration of the character of the motion, I have plotted from the central star the observed positions for each year represented by measures. These are shown by the black circles outside the ellipse. Where more than one observer has measured it in a single year, a simple mean has been taken of all the measures. Only two observations have been omitted from the means, and both because the distances

were manifestly absurd. The angles and distances of the several positions were laid down with all possible accuracy, but in order to avoid confusing the two sets, the scale of distances for the observed positions is one and one-half time the scale used in laying down the first positions. The divided scale of 1″·0 shown on the diagram has reference to the white circles.

Certainly these positions appear to show orbital motion beyond all question. If there is any doubt in regard to this, then it follows as a matter of course that no binary system is positively known as such, where the period is more than 300 years.

The ellipse shown on fig. 2 gives a period of 310 years. This may or may not be somewhere near the correct time. A variety of curves may be passed through these corrected positions, where the arc is only 90°, and represent them equally well. The most that can be said of this is, that the period will not be less than 300 years, while it may be considerably longer. Casey's period of 340 years can be made to suit these positions, but in other respects it would differ, and particularly in the eccentricity. It will be observed that the real orbit shown on the diagram is circular, while the computed orbit has an eccentricity of 0·30.

In the Albany Zone Observations (*Astronomical Journal*, No. 200) Boss gives the annual proper motion of the mean of the two components as 0″·184 in the direction of 277°·2. Assuming this to be the movement of the principal star, then if the relative change is due to proper motion, the companion would have an annual motion of 0″·197 in the direction of 283°.

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The Orbit of 40 *Eridani*, Σ 518. By S. W. Burnham, M.A.

The double companion to 40 *Eridani* was discovered by Herschel in 1783. It was next observed by Struve in 1825, but was too difficult to measure. The measures of precision really commence with the observations of O. Struve in 1851. Since that time it has been looked after by the various double star observers, and the arc of nearly 60°, through which the small star has passed in the last forty years, is very well defined, and the measures as a whole appear to be fairly satisfactory. The mean angular change has been about one degree and a half per year, but it is obvious that the apparent ellipse is a very elongated one, and therefore the average motion for a complete revolution will be a much smaller quantity.

Though the period is long, this is an interesting binary from the large proper motion of the system. Only four stars in the northern hemisphere have a larger proper motion. This is common to the principal star, and to the binary companion which is more than 80″ distant. Hall finds a parallax for A of 0″·22, so that the system is comparatively near the Earth.